Software Tool for Assessment of Complexity and Variability in Physiological Signals of Respiration

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ABSTRACT

In this paper, the authors examine software implementation and the initial preprocessing of data and tools during the assessment of the complexity and variability of long physiological time-series. The algorithms presented advance a bigger Matlab library devoted to complex system and data analysis. Commercial software is unavailable for many of these functions and is generally unsuitable for use with multi-gigabyte datasets. Reliable inter-event time extraction from input signal is an important step for the presented considerations. Knowing the distribution of the inter-event time distances, it is possible to calculate exponents due to power-law scaling. From a methodology point of view, simulations and considerations with experimental data supported each stage of the work presented. In this paper, initial calibration of the procedures with accessible data confirmed assessments made during earlier studies, which raise objectivity of measurements planned in the future.

Keywords: Biological Signal Modeling, Complexity Theory, Respiratory Measurements, Sleep Apnea Syndrome, Time Series Analysis

1. INTRODUCTION

Metrology as the interdisciplinary science cumulates the knowledge across many theoretical and experimental disciplines. As a result, it offers the new strategies for object inspection, each concerning the concept of an efficient measurement scheme, i.e., minimal invasive, quick, reliable, cheap and easy accessible protocol. Minimal invasiveness is especially important feature of measurement scheme when the properties of living organisms are observed. On the other hand, the life world is an example of the object where many kinds of processes occur. These processes can be free-scale, and exhibit numerous (isolated or not) components of variability, e.g., non-linearity, stochasticity, non-stationarity. Hence, a quite substantial...
The challenge is the reconstruction of system state with acquired signals comprehended as a conglomerate of entangled processes (Bruce, 1996). One more issue is a structural organization of physiological systems, which typically reveals complex systematics at various levels (Tawhai, & Bates, 2011). It is also well known that structural changes observed across the macro to micro world result in patterned forms of fractal nature (Thamrin, Stern, & Frey 2010). All these are useful source of information for diagnostic evaluations and predictions, and the same issue of complexity and variability is a subject of numerous theoretical and experimental investigations and reports (Pincus, 1991; Webber & Zbilut, 1994; Bruce, 1996; Eke et al., 2002; West, Geneston, & Grigolini, 2008).

The respiratory system is the example of physiological object, which works in tight interactions with the other subsystems. For example, a central nervous system and cardiological signals can control it internally, whereas the external inputs of air pollutants can bring to the immuno-reactions triggering a pathological behavior in a short- or long-term horizon (Frey et al., 2005, 2011; Pearce & Merletti, 2006). The question for engineer and scientists engaged in biomedical aspects of metrology is how to disentangle the information contained in complex and varying sets of physiological data.

Operation with experimental data assumes not only defining the newer and newer construction of abstract measures quantifying the complex processes, but also their application to real data of various lengths. Insufficient progression in development of algorithms adapted to working with long sets of data is one of the causes which slow down the work devoted to designing of the optimal measurement protocol for respiratory diagnostics. Advances in the field of complex biomedical signal analysis have also been limited by lack of concentrated and concerted research efforts (Goldberger et al., 2000). Furthermore, advanced analytic techniques developed by experts in the field are often not readily accessible to end users (e.g., clinicists), who may lack the background and technical skills needed for the successful use of these new tools.

The paper deals with the issue of respiratory measurements by characterization of complexity and variability of outputs with the use of authorial software library. Universal use of the tool enables monitoring and systematization of a broad range of respiratory pathologies, e.g., asthma, cystic fibrosis, sleep apnea syndrome, and the procedures can be also applied for the other biomedical or technical tasks.

### 2. SOFTWARE LIBRARY FOR COMPLEXITY ANALYSIS

#### A. Initial Preprocessing of Data

Working with long sets of data can be ineffective and requires allocation of important memory resources in a computational unit. Additionally, very often it is a need for transformation of the whole string of data or its parts. To facilitate the task of initial preprocessing of data to complexity and fluctuation analysis, a dedicated application with a graphical interface was designed in Matlab. Its main tasks are:

- Loading the data from ASCII file containing the one-column data format or multi-column record of polisomnography (application identifies the channel for a built-in data format and a given device),
- Viewing the analyzed time series (in a whole range or zoomed),
- Windowing the data for further processing (the number of first sample and the whole number of samples in the window can be chosen optionally),
- Enabling access to numerous procedures of initial data preprocessing (e.g., filtering, extracting the special features of time series, etc.),
- Writing the transformed data to the file(es), also in the mode of multi-window division of data (windows can overlaps each other with the defined number of samples).
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